

# Using the TPS53353EVM-744, High-Efficiency, 20-A, Synchronous Buck Converter With Eco-mode™ Control Scheme

The TPS53353EVM-744 evaluation module (EVM) demonstrates the TPS53353. The TPS53353 is a D-CAP™ mode, 20-A, synchronous buck converter with integrated MOSFETs. It provides a fixed 1.5-V output at up to 20 A from a 12-V input bus.

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## 1 Description

The TPS53353EVM-744 is designed to use a regulated 12-V bus to produce a regulated 1.5-V output at up to 20 A of load current. The TPS53353EVM-744 is designed to demonstrate the TPS53353 in a typical low-voltage application while providing a number of test points to evaluate the performance of the TPS53353.

### 1.1 Typical Application

- Server/storage
- Workstations and desktops
- Telecommunication infrastructure

### 1.2 Features

The TPS53353EVM-744 features:

- 20-Adc, steady-state output current
- Support prebias output voltage start-up
- J5 for selectable switching frequency setting
- J4 for selectable soft-start time
- J2 for enable function
- J6 for auto-skip and forced CCM selection
- Convenient test points for probing critical waveforms

## 2 Electrical Performance Specifications

**Table 1. TPS53353EVM-744 Electrical Performance Specifications**

Parameter	Test Conditions	Min	Typ	Max	Units
<b>Input Characteristics</b>					
Voltage range	$V_{IN}$	8	12	14	V
Maximum input current	$V_{IN} = 8\text{ V}$ , $I_O = 20\text{ A}$		4.1		A
No-load input current	$V_{IN} = 14\text{ V}$ , $I_O = 0\text{ A}$ with auto-skip mode		1		mA
<b>Output Characteristics</b>					
Output voltage $V_{OUT}$			1.5		V
Output voltage regulation	Line regulation ( $V_{IN} = 8\text{ V} - 14\text{ V}$ )		0.1		%
	Load regulation ( $V_{IN} = 12\text{ V}$ , $I_O = 0\text{ A} - 20\text{ A}$ )		1		
Output voltage ripple	$V_{IN} = 12\text{ V}$ , $I_O = 20\text{ A}$		20		mVpp
Output load current		0		20	A
Output overcurrent			26		A
<b>Systems Characteristics</b>					
Switching frequency			500		kHz
Peak efficiency	$V_{IN} = 12\text{ V}$ , 1.5 V/10 A		91.87		%
Full-load efficiency	$V_{IN} = 12\text{ V}$ , 1.5 V/20 A		91.38		%
Operating temperature			25		°C

**NOTE:** Jumpers are set at the factory to default locations; for details, see [Section 5](#) of this user's guide

3 Schematic

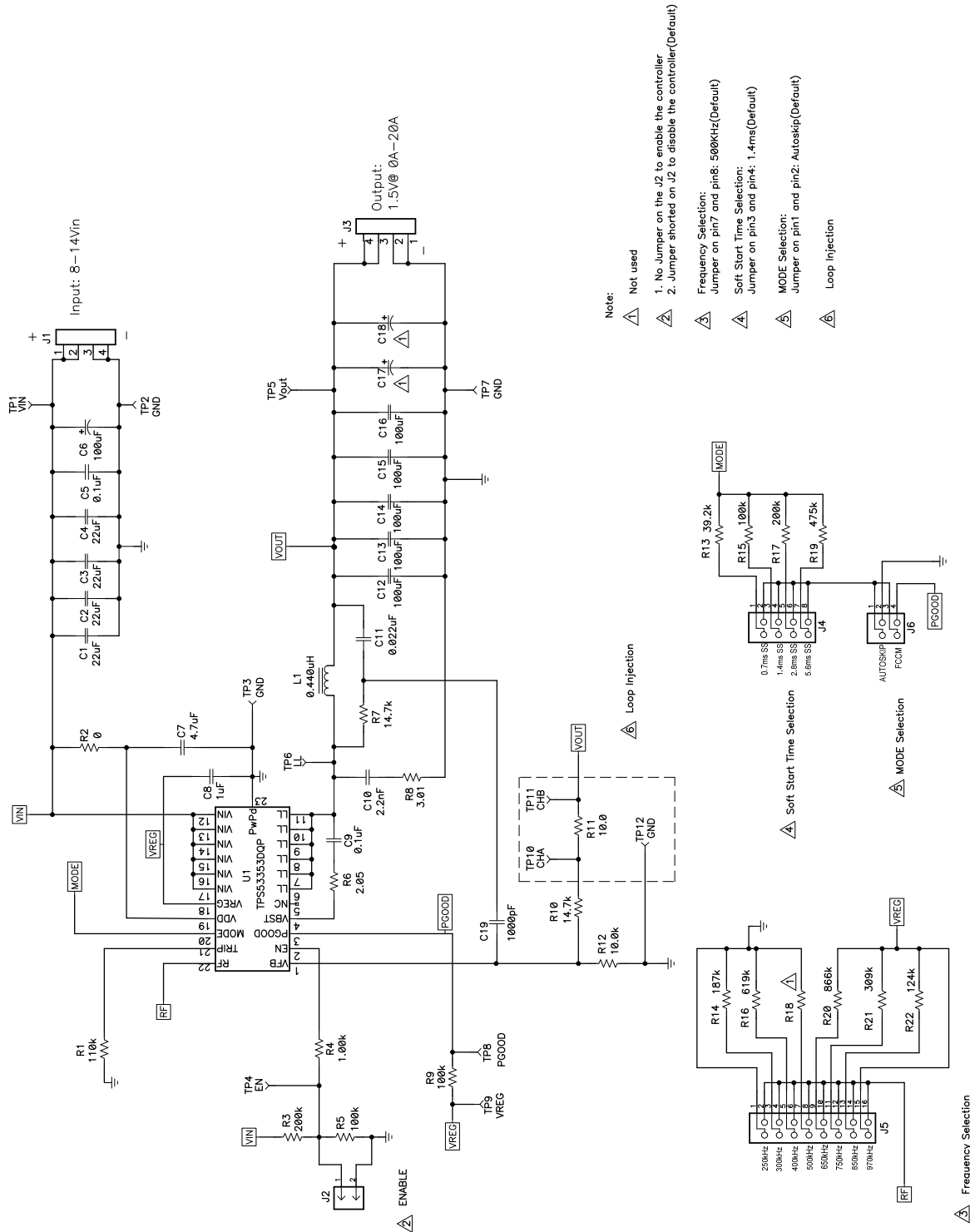


Figure 1. TPS53353EVM-744 Schematic

## 4 Test Setup

### 4.1 Test Equipment

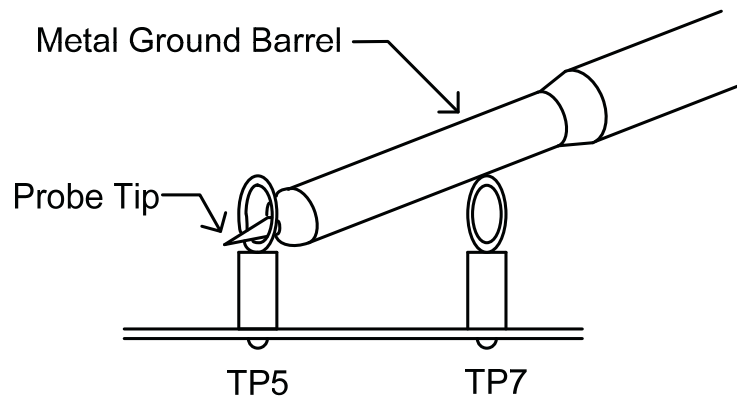
**Voltage Source:** The input voltage source  $V_{IN}$  must be a 0-V to 14-V variable dc source capable of supplying 10 Adc. Connect  $V_{IN}$  to J1 as shown in [Figure 3](#).

**Multimeters:**

- V1:  $V_{IN}$  at TP1 ( $V_{IN}$ ) and TP2 (GND).
- V2: VOUT at TP5 (VOUT) and TP7 (GND).
- A1:  $V_{IN}$  input current

**Output Load:** The output load should be an electronic constant resistance mode load capable of 0-30ADC at 1.5V.

**Oscilloscope:** A digital or analog oscilloscope can be used to measure the output ripple. The oscilloscope must be set for 1-M $\Omega$  impedance, 20-MHz bandwidth, ac coupling, 2- $\mu$ s/division horizontal resolution, 50-mV/division vertical resolution. Test points TP5 and TP7 can be used to measure the output ripple voltage by placing the oscilloscope probe tip through TP5 and holding the ground barrel on TP7 as shown in [Figure 2](#). Using a leaded ground connection may induce additional noise due to the large ground loop.



**Figure 2. Tip and Barrel Measurement for Vout Ripple**

**Fan:** Some of the components in this EVM may approach temperatures of 60°C during operation. A small fan capable of 200-400 LFM is recommended to reduce component temperatures while the EVM is operating. The EVM must not be probed while the fan is not running.

**Recommended Wire Gauge:**

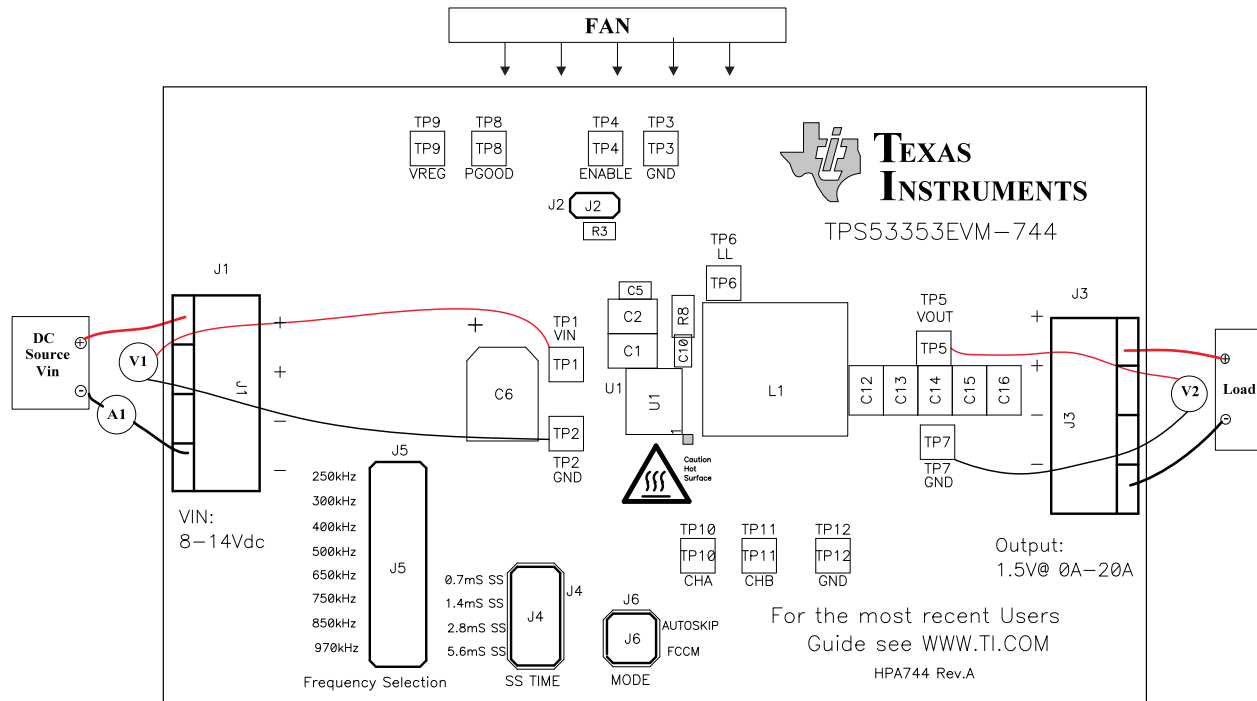
1.  $V_{IN}$  to J1 (12-V input):

The recommended wire size is 1x AWG 14 per input connection, with the total length of wire less than 4 feet (2-foot input, 2-foot return).

2. J3 to LOAD:

The minimum recommended wire size is 2x AWG 14, with the total length of wire less than 4 feet (2-foot input, 2-foot return)

## 4.2 Recommended Test Setup



**Figure 3. TPS53353EVM-744 Recommended Test Setup**

Figure 3 is the recommended test setup to evaluate the TPS53353EVM-744. Working at an ESD workstation, make sure that any wrist straps, bootstraps or mats are connected referencing the user to earth ground before power is applied to the EVM.

### Input Connections:

1. Before connecting the dc input source  $V_{IN}$ , it is advisable to limit the source current from  $V_{IN}$  to 10 A maximum. Ensure that  $V_{in}$  is initially set to 0 V and connected as shown in Figure 3.
2. Connect a voltmeter V1 at TP1( $V_{IN}$ ) and TP2(GND) to measure the input voltage.
3. Connect a current meter A1 to measure the input current.

### Output Connections:

1. Connect Load to J3, and set Load to constant resistance mode to sink 0 A before  $V_{in}$  is applied.
2. Connect a voltmeter V2 at TP5 ( $V_{out}$ ) and TP7(GND) to measure the output voltage.

### Other Connections:

Place a fan as shown in Figure 3, and turn it on, ensuring that air is flowing across the EVM.

## 5 Configurations

All jumper selections must be made prior to applying power to the EVM. Users can configure this EVM per following configurations.

### 5.1 Switching Frequency Selection

Use J5 to set the switching frequency.

**Default setting: 500 kHz**

**Table 2. Switching Frequency Selection**

Jumper Set To	Resistor (RF) Connections (k $\Omega$ )	Switching Frequency (kHz)
Top (1-2 pin shorted)	0	250
Second (3-4 pin shorted)	187	300
Third (5-6 pin shorted)	619	400
<b>Fourth (7-8 pin shorted)</b>	<b>Open</b>	<b>500</b>
Fifth (9-10 pin shorted)	866	650
Sixth (11-12 pin shorted)	309	750
Seventh (13-14 pin shorted)	124	850
Bottom (15-16 pin shorted)	0	970

### 5.2 Soft-Start Selection

Use J4 to set the soft-start time..

**Default setting: 1.4 ms**

**Table 3. Soft-Start Time Selection**

Jumper Set To	R <sub>MODE</sub> Connections (k $\Omega$ )	Soft-Start Time (ms)
Top (1–2 pin shorted)	39.2	0.7
<b>Second (3–4 pin shorted)</b>	<b>100</b>	<b>1.4</b>
Third (5–6 pin shorted)	200	2.8
Fourth (7–8 pin shorted)	475	5.6

### 5.3 Mode Selection

Use J6 to set the MODE.

**Default setting: Auto Skip**

**Table 4. MODE Selection**

Jumper Set To	R <sub>MODE</sub> Connections ( $\Omega$ )
<b>Top (1–2 pin shorted)</b>	<b>Auto Skip</b>
Second (3–4 pin shorted)	Forced CCM



## 5.4 Enable Selection

Use J2 to enable and disable the controller.

**Default setting: Jumper shorts on J2 to disable the controller**

**Table 5. Enable Selection**

Jumper Set To	Enable Selection
Jumper shorts on J2	Disable the controller
No Jumper shorts on J2	Enable the controller

## 6 Test Procedure

### 6.1 Line/Load Regulation and Efficiency Measurement Procedure

1. Set up EVM as described in [Section 4](#) and [Figure 3](#).
2. Ensure that Load is set to constant resistance mode and to sink 0 Adc.
3. Ensure that all jumpers configuration settings are per [Section 5](#).
4. Ensure that the jumper provided in the EVM shorts on J2 before  $V_{IN}$  is applied.
5. Increase  $V_{in}$  from 0 V to 12 V, using V1 to measure input voltage.
6. Remove the jumper on J2 to enable the controller.
7. Use V2 to measure  $V_{out}$  voltage.
8. Vary Load from 0 Adc to 20 Adc;  $V_{OUT}$  must remain in load regulation.
9. Vary  $V_{in}$  from 8 V to 14 V;  $V_{OUT}$  must remain in line regulation.
10. Put the jumper on J2 to disable the controller.
11. Decrease Load to 0 A.
12. Decrease  $V_{IN}$  to 0 V.

### 6.2 Control Loop Gain and Phase Measurement Procedure

TPS53353EVM-744 contains a 10- $\Omega$  series resistor in the feedback loop for loop response analysis.

1. Set up EVM as described in [Section 4](#) and [Figure 3](#).
2. Connect isolation transformer to test points marked TP10 and TP11.
3. Connect input signal amplitude measurement probe (channel A) to TP10. Connect output signal amplitude measurement probe (channel B) to TP11.
4. Connect ground lead of channel A and channel B to TP12.
5. Inject approximately 40 mV or less signal through the isolation transformer.
6. Sweep the frequency from 100 Hz to 1 MHz with a 10-Hz or lower post filter. The control loop gain and phase margin can be measured.
7. Disconnect isolation transformer from bode plot test points before making other measurements. (Signal injection into feedback may interfere with accuracy of other measurements.)

### 6.3 Test Point List

**Table 6. Test Point Functions**

Test Points	Name	Description
TP1	VIN	Controller input
TP2	GND	Ground
TP3	GND	Ground
TP4	EN	Enable
TP5	V <sub>OUT</sub>	Output voltage
TP6	LL	Switching node
TP7	GND	Ground
TP8	PGOOD	Power Good
TP9	VREG	5-V LDO output
TP10	CHA	Input A for loop injection
TP11	CHB	Input B for loop injection
TP12	GND	GND

### 6.4 Equipment Shutdown

1. Shut down Load.
2. Shut down V<sub>IN</sub>.
3. Shut down fan.

## 7 Performance Data and Typical Characteristic Curves

Figure 4 through Figure 18 present typical performance curves for TPS53353EVM-744.

### 7.1 Efficiency

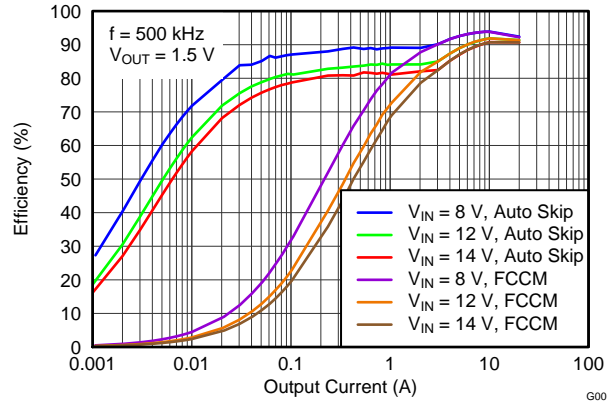


Figure 4. Efficiency

### 7.2 Load Regulation

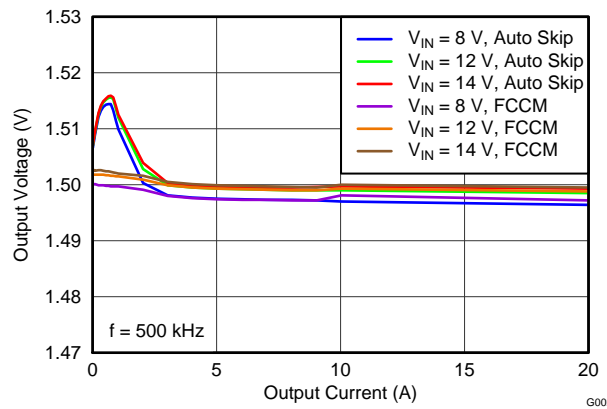


Figure 5. Load Regulation

### 7.3 Load Regulation

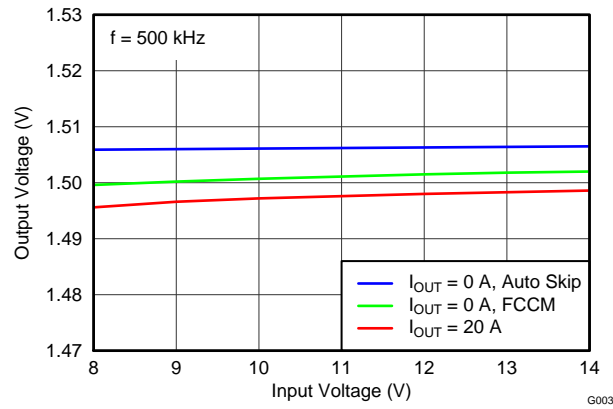


Figure 6. Line Regulation

### 7.4 Enable Turnon/ Turnoff

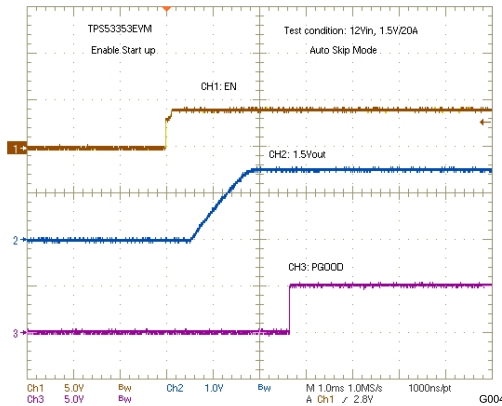


Figure 7. Enable Turnon

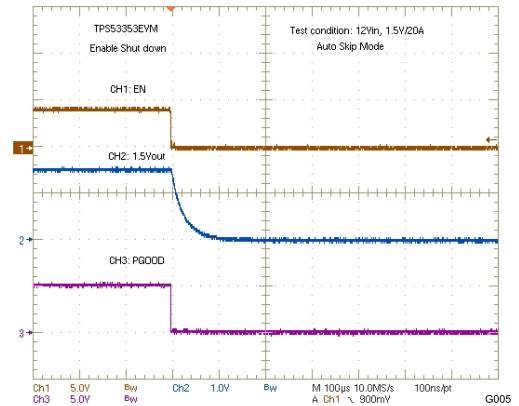


Figure 8. Enable Turnoff

## 7.5 Output Ripple

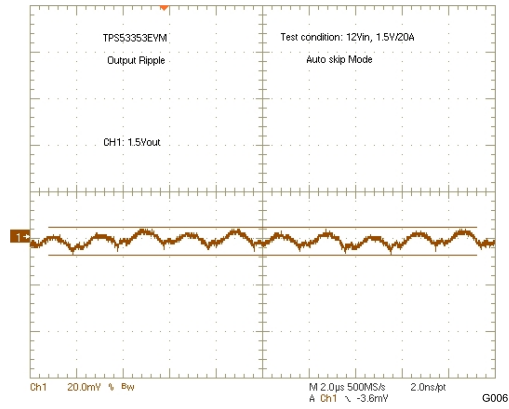


Figure 9. Output Ripple

## 7.6 Switching Node

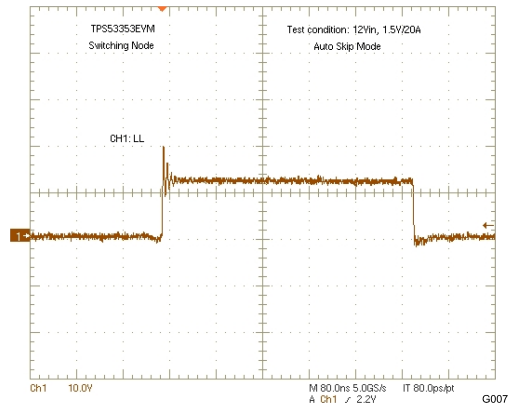


Figure 10. Switching Node

### 7.7 Output Transient With Auto-Skip Mode

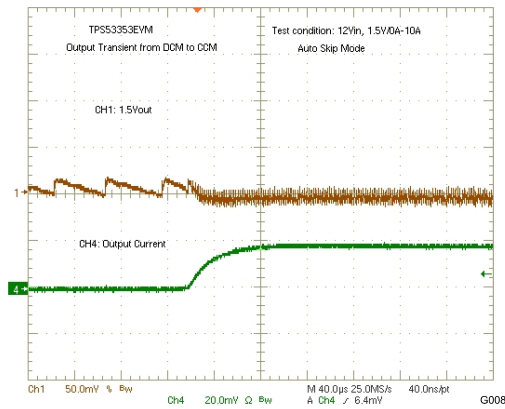


Figure 11. Output Transient From DCM to CCM

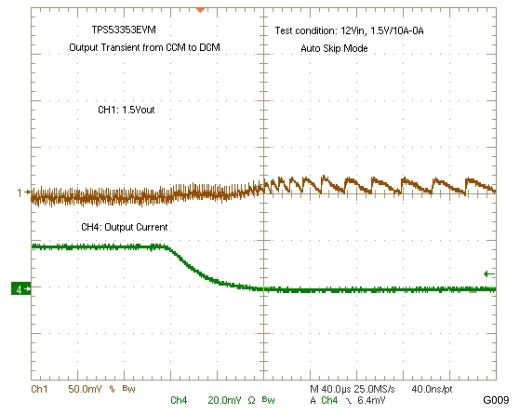


Figure 12. Output Transient From CCM to DCM

### 7.8 Output Transient With FCCM Mode

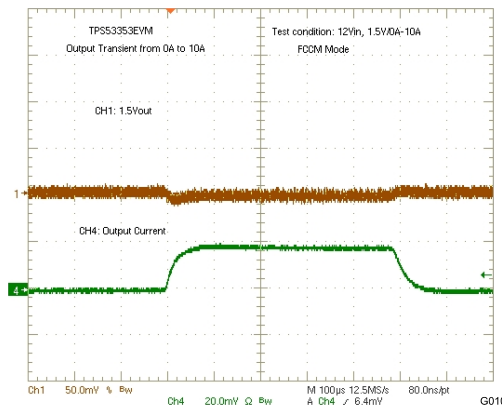


Figure 13. Output Transient With FCCM Mode

### 7.9 Output 0.75-V Prebias Turnon

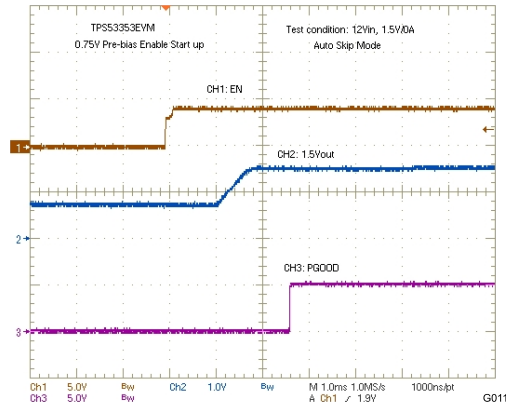


Figure 14. Output 0.75-V Prebias Turnon

### 7.10 Output Overcurrent and Short-Circuit Protection

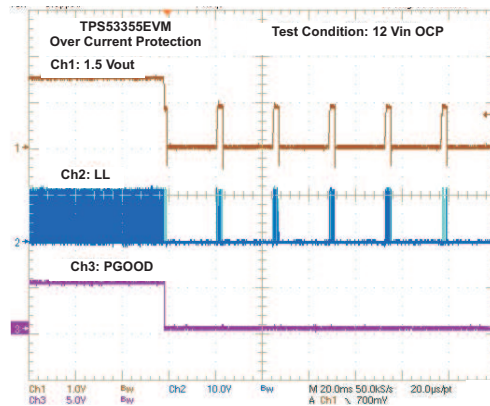


Figure 15. Output Overcurrent Protection

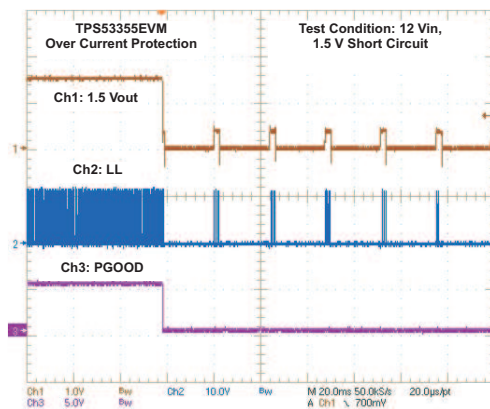
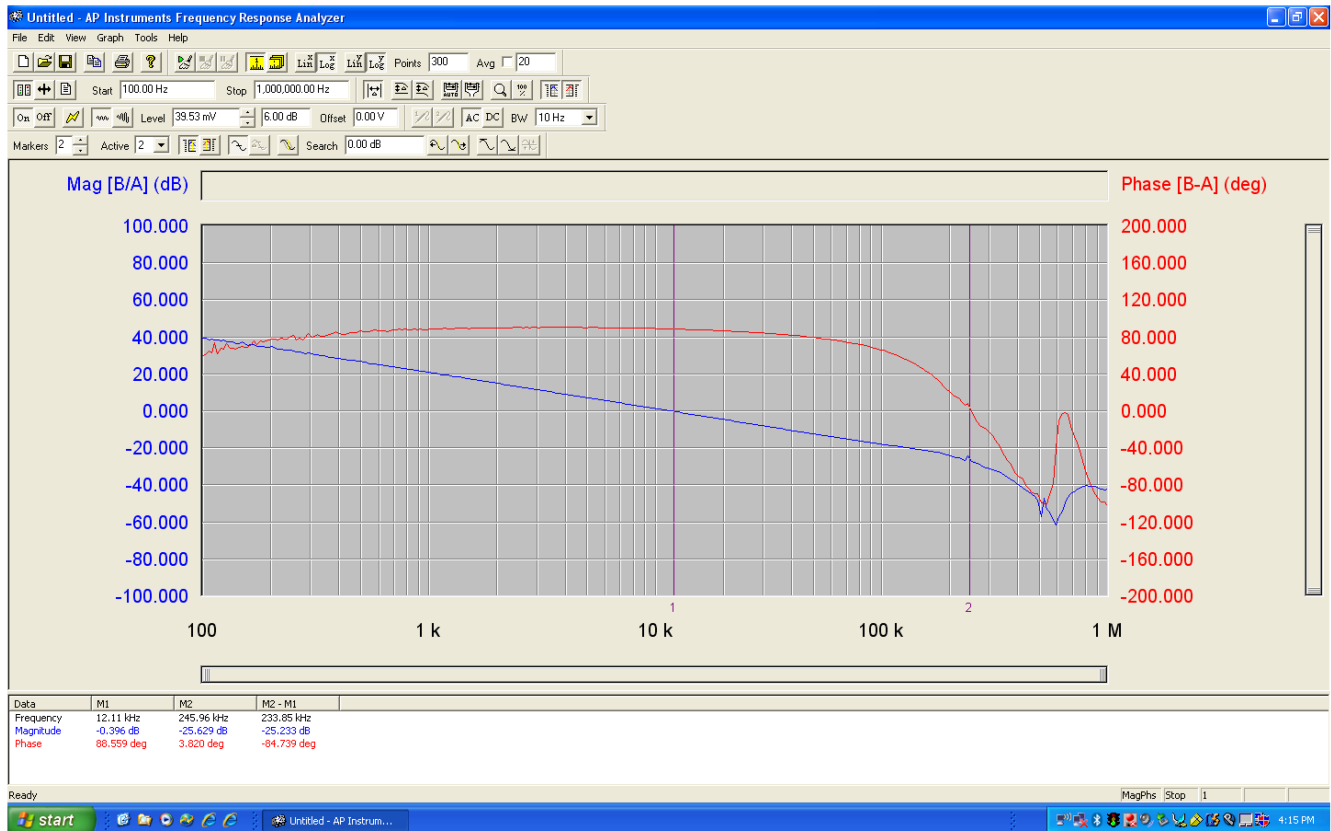


Figure 16. Output Short Circuit

### 7.11 Bode Plot



G012

Figure 17. Bode Plot at 12 V<sub>IN</sub>, 1.5 V/20 A



## 7.12 Thermal Image

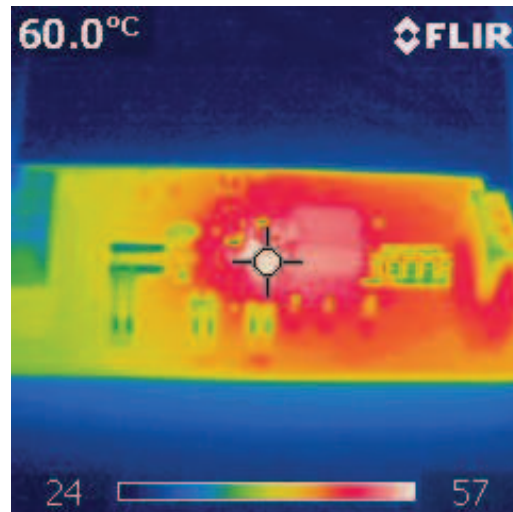


Figure 18. Top Board at 12 V<sub>IN</sub>, 1.5 V/20 A, 25°C Ambient Temperature Without Airflow

### 8 EVM Assembly Drawing and PCB Layout

The following figures (Figure 19 through Figure 26) show the design of the TPS53353EVM-744 printed-circuit board (PCB). The EVM was designed using a 6-layer, 2-oz copper, PCB.

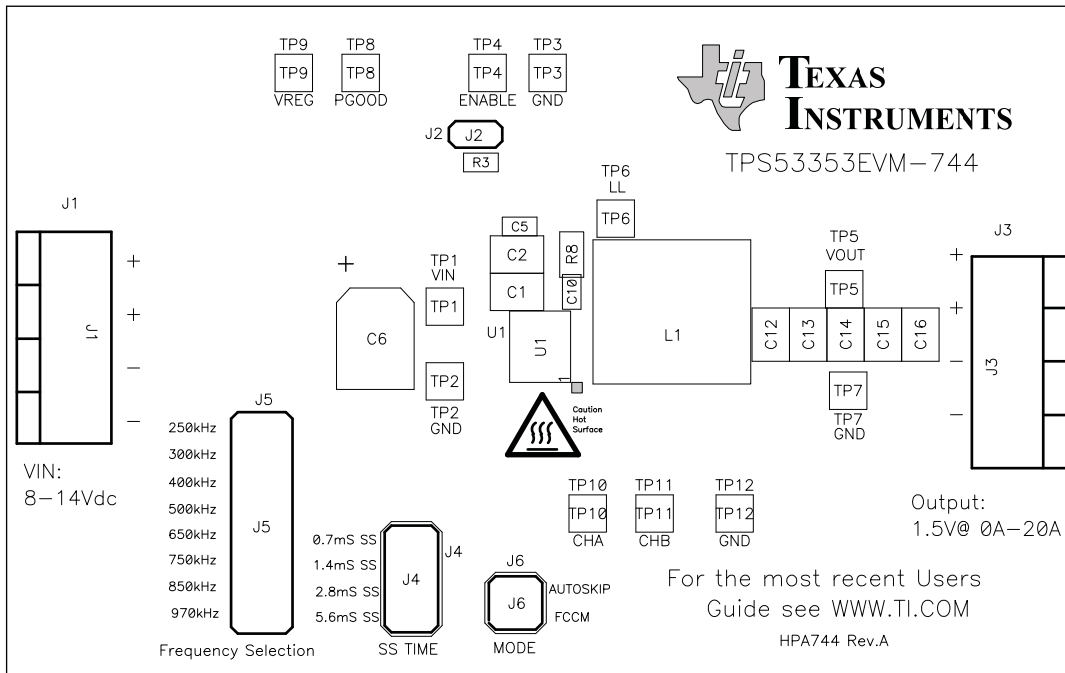


Figure 19. TPS53353EVM-744 Top Layer Assembly Drawing

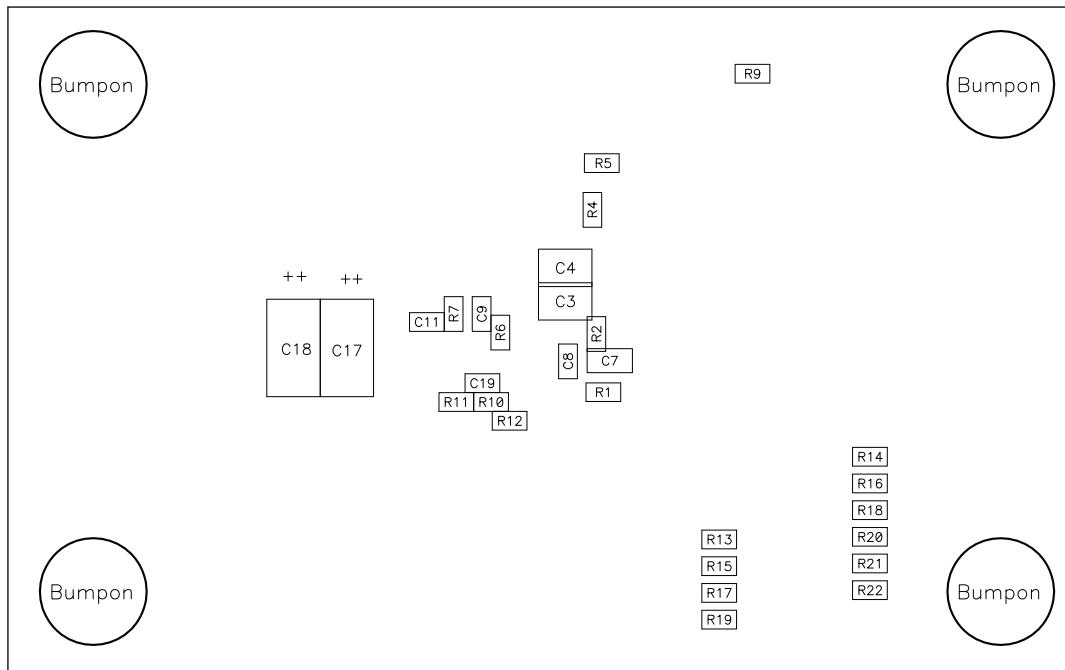


Figure 20. TPS53353EVM-744 Bottom Assembly Drawing

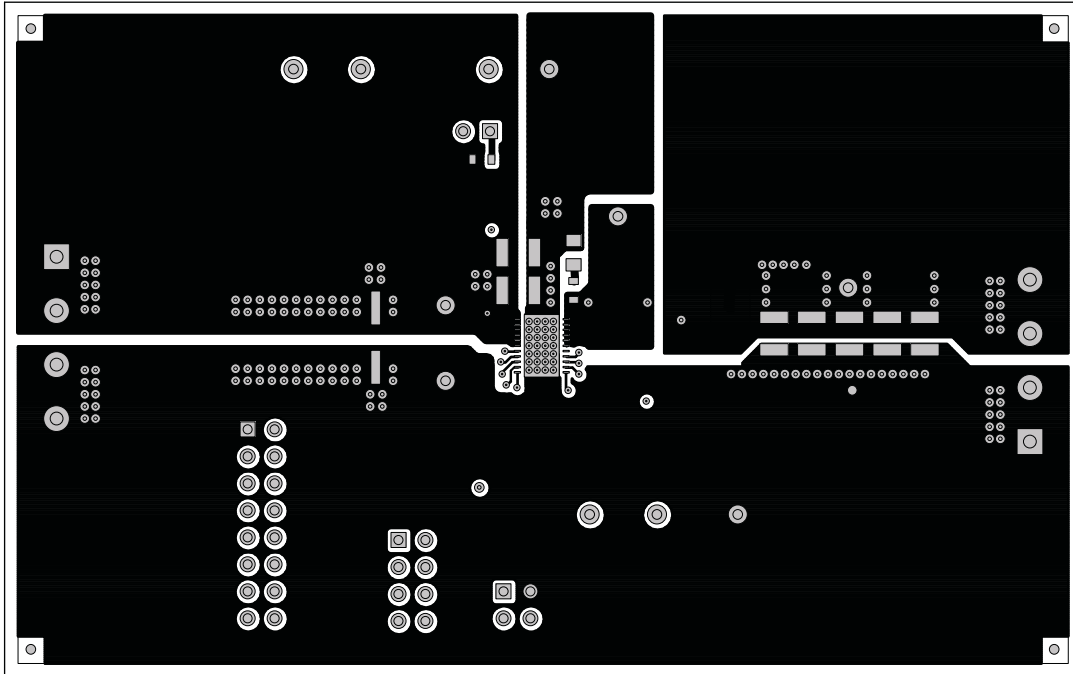


Figure 21. TPS53353EVM-744 Top Copper

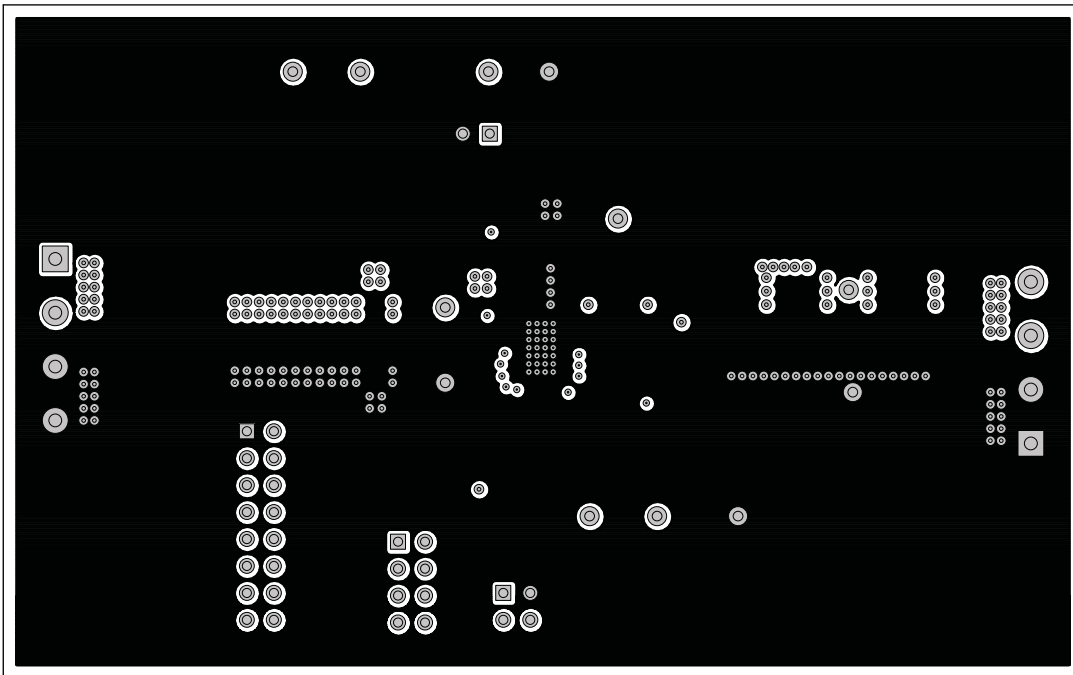
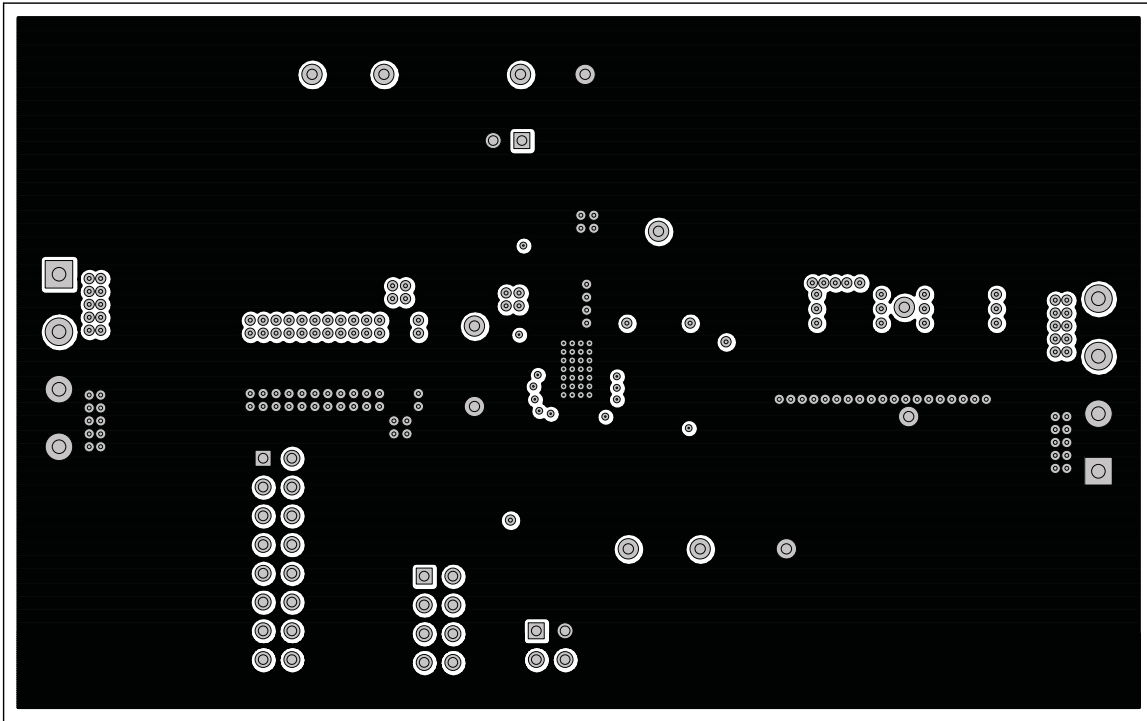
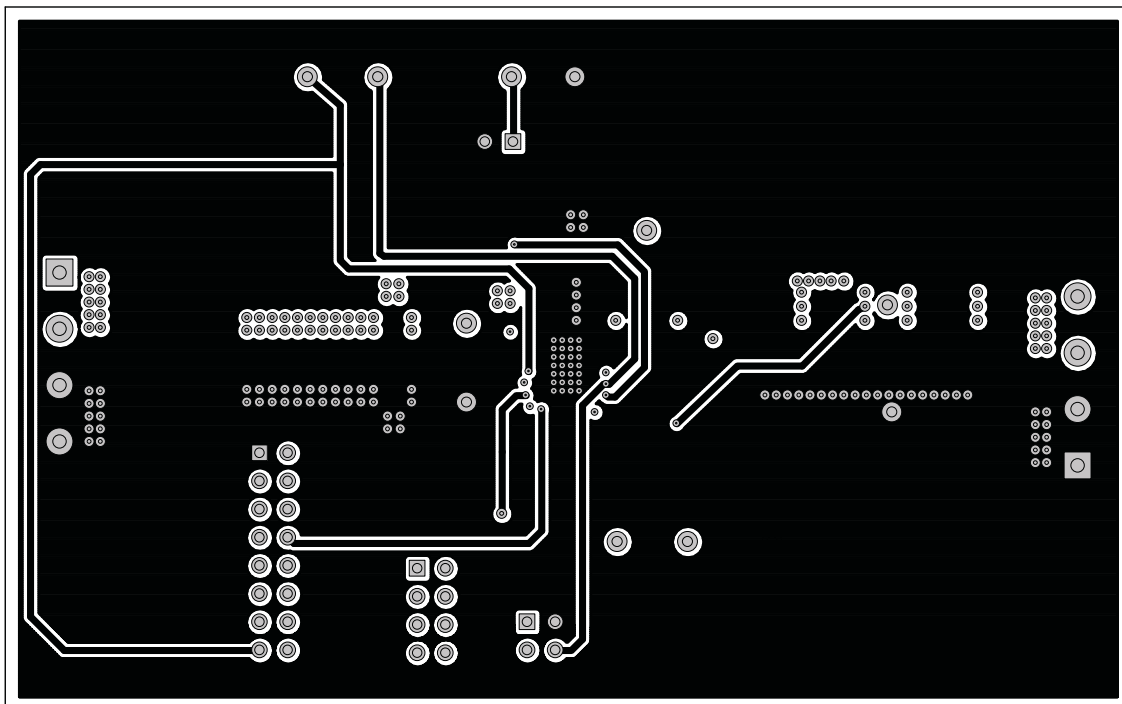


Figure 22. TPS53353EVM-744 Layer-2 Copper



**Figure 23. TPS53353EVM-744 Layer-3 Copper**



**Figure 24. TPS53353EVM-744 Layer-4 Copper**

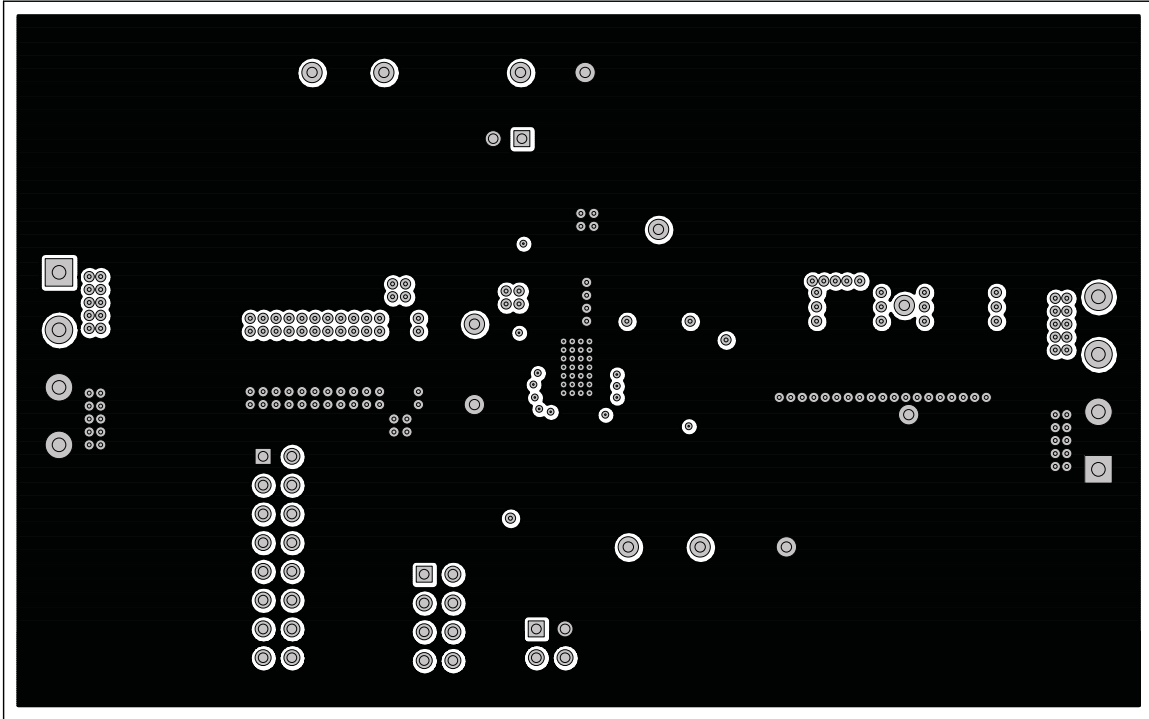


Figure 25. TPS53353EVM-744 Layer-5 Copper

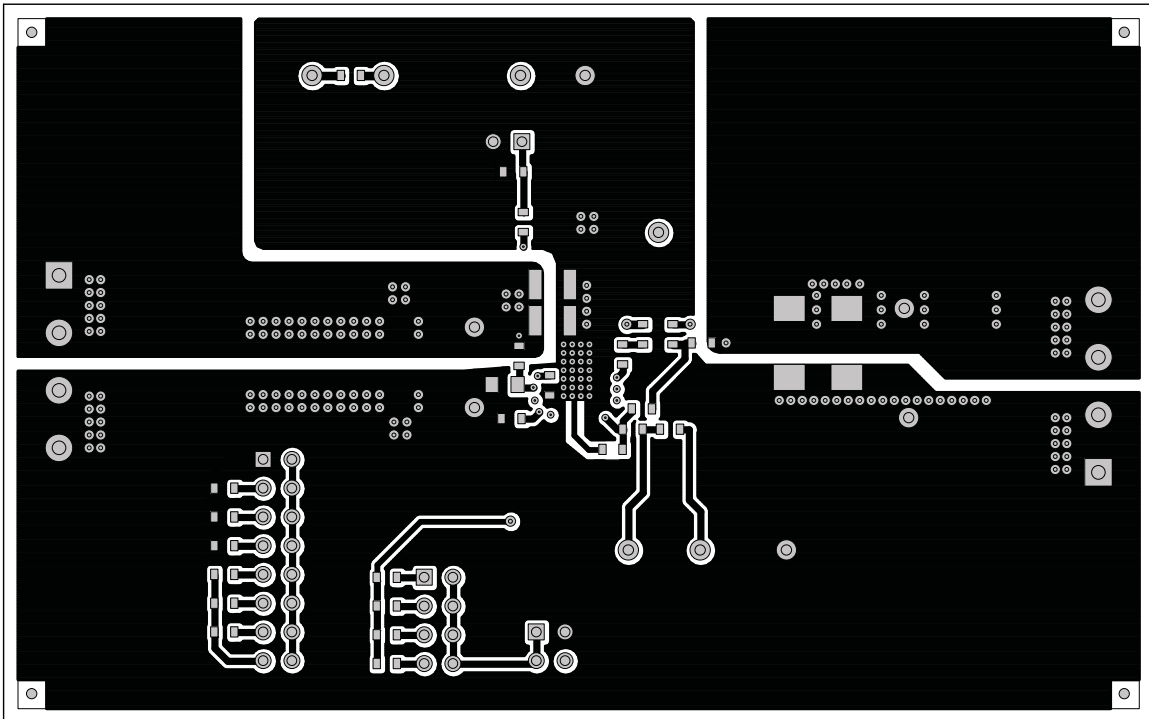


Figure 26. TPS53353EVM-744 Bottom Layer Copper

**9 Bill of Materials**
**Table 7. TPS53353EVM-744 Bill of Materials**

QTY	REFDES	DESCRIPTION	MFR PART	NUMBER
4	C1, C2, C3, C4	Capacitor, Ceramic, 22uF, 16V, X5R, 20%, 1210	MURATA	GRM32ER61C226KE20L
5	C12, C13, C14, C15, C16	Capacitor, Ceramic, 100uF, 6.3V, X5R, 20%, 1210	MURATA	GRM32ER60J107ME20L
1	C10	Capacitor, Ceramic, 2.2nF, 50V, X7R, 20%, 0603	STD	STD
1	C11	Capacitor, Ceramic, 0.022uF, 50V, X7R, 20%, 0603	STD	STD
1	C19	Capacitor, Ceramic, 1000pF, 50V, X7R, 20%, 0603	STD	STD
2	C5, C9	Capacitor, Ceramic, 0.1uF, 50V, X7R, 20%, 0603	STD	STD
1	C6	Capacitor, Aluminum, 100uF, 16VDC, 20%, Code D8	Panasonic	EEEF1C101AP
1	C7	Capacitor, Ceramic, 4.7uF, 25V, X5R, 20%, 0805	STD	STD
1	C8	Capacitor, Ceramic, 1uF, 50V, X7R, 20%, 0603	STD	STD
1	L1	Inductor, SMT, 0.44uH, 30A, 0.0032ohms, 0.53"x0.510"	Pulse	PA0513-441NLT
1	R1	Resistor, Chip, 110k, 1/16W, 1%, 0603	STD	STD
1	R11	Resistor, Chip, 10, 1/16W, 1%, 0603	STD	STD
1	R12	Resistor, Chip, 10.0k, 1/16W, 1%, 0603	STD	STD
1	R13	Resistor, Chip, 39.2k, 1/16W, 1%, 0603	STD	STD
1	R14	Resistor, Chip, 187k, 1/16W, 1%, 0603	STD	STD
1	R16	Resistor, Chip, 619k, 1/16W, 1%, 0603	STD	STD
1	R19	Resistor, Chip, 475k, 1/16W, 1%, 0603	STD	STD
1	R2	Resistor, Chip, 0, 1/16W, 1%, 0603	STD	STD
1	R20	Resistor, Chip, 866k, 1/16W, 1%, 0603	STD	STD
1	R21	Resistor, Chip, 309k, 1/16W, 1%, 0603	STD	STD
1	R22	Resistor, Chip, 124k, 1/16W, 1%, 0603	STD	STD
2	R3, R17	Resistor, Chip, 200k, 1/16W, 1%, 0603	STD	STD
3	R5, R9, R15	Resistor, Chip, 100k, 1/16W, 5%, 0603	STD	STD
1	R4	Resistor, Chip, 1.00k, 1/16W, 1%, 0603	STD	STD
1	R6	Resistor, Chip, 2.05, 1/16W, 1%, 0603	STD	STD
2	R7, R10	Resistor, Chip, 14.7k, 1/16W, 1%, 0603	STD	STD
1	R8	Resistor, Chip, 3.01, 1/16W, 1%, 0805	STD	STD
1	U1	IC, 20A Synchronous Buck converter with integrated MOSFETs, DQP-22	TI	TPS53353DQP

## Evaluation Board/Kit Important Notice

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## EVM Warnings and Restrictions

It is important to operate this EVM within the input voltage range of 8 V to 14 V and the output voltage range of 0.6 V to 5.5 V .

Exceeding the specified input range may cause unexpected operation and/or irreversible damage to the EVM. If there are questions concerning the input range, please contact a TI field representative prior to connecting the input power.

Applying loads outside of the specified output range may result in unintended operation and/or possible permanent damage to the EVM. Please consult the EVM User's Guide prior to connecting any load to the EVM output. If there is uncertainty as to the load specification, please contact a TI field representative.

During normal operation, some circuit components may have case temperatures greater than 60°C. The EVM is designed to operate properly with certain components above 60°C as long as the input and output ranges are maintained. These components include but are not limited to linear regulators, switching transistors, pass transistors, and current sense resistors. These types of devices can be identified using the EVM schematic located in the EVM User's Guide. When placing measurement probes near these devices during operation, please be aware that these devices may be very warm to the touch.

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